

Tests of piles in melted and frozen soils in creep mode: relaxation conditions

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Abstract. A new method for the experimental determination of bearing capacity of piles is considered, which makes it possible to determine separately within one test the resistance under the lower end and along the lateral surface of piles in melted soils, the similar parameters for piles frozen in permafrost soils inclusive. The purpose of work is the development of a new test method, which allows to increase the accuracy and informative nature of tests and significantly shorten their time and cost. The proposed method is based on the dynamometric method for determining the long-term strength of soils in creep-relaxation regime proposed by Professor S.S. Vyalov. The essence of the proposed method for testing the immersed pile loaded with static load in a thawed ground is that the pile tested is immersed statically loaded at some depth, and after that it is tested in the creep-relaxation regime. After stabilizing the relaxing load, a step-up pulling load is applied to the pile, where each stage of the load is tested in the creep-relaxation regime. Maximum value of the stabilized pulling load can be considered as the sum of frictional forces along the lateral surface of the pile immersed to a given depth. The difference in the stabilized load of indentation and pulling out shall be equal to the resistance of pile under its lower end. By immersing the pile at different depths and testing it at each point in the manner described above, it seems possible to obtain the separate resistance values along the lateral surface and under the lower end of the pile at different depths. For frozen soils, the pile frozen into the ground is tested in the similar way, i.e. by indenting and pulling out thereof the creep-relaxation regime. To determine the bearing capacity of piles frozen in frozen ground at different negative temperatures during one test, the stock pile is first tested in creep-relaxation mode at a fixed maximum negative temperature value. After the stabilized value of the indentation and then pulling load is reached, the temperature around the pile is stepwise changed, and at each temperature value the stabilized values of the compressive and pulling loads are determined. The theoretical justification and results of field and laboratory testing of the proposed test method are outlined. The description of results of comparative experiments and the equipment used is also given. The comparison of the proposed test method is in good agreement with the results of experiments performed by traditional methods. This method can be successfully used with significant cost and time savings in course of construction and reconstruction of structures on pile foundations both for thawed and frozen soils.



1. Introduction

Piling of piles into the ground is usually carried out by driving, screwing, vibrating or crushing with the use of static loads. The method of immersing piles by means of static loading has several significant advantages. This does not create a dynamic load on the soil base, the pile head is not broken; besides the method is implemented almost silently, which is very important for the construction of objects near residential buildings. Since the subsequent load from the structure will be less than the pile's crushing force, if the immersed pile is fixed in foundation frame under some load, then its settlement during operation of the structure will be equal to zero. In addition, by the force of the pile immersion it is possible to determine the actual bearing capacity of the pile installed [1, 2, 3]. Therefore, this method is increasingly used not only in the reinforcement of foundations of reconstructed buildings, but also in new construction. Up to date, high-performance equipment for drawing the static loaded piling has been developed [4, 5]. There are developments that allow to improve load-bearing capacity of the pile squeezed [6].

For piles squeezed the bearing capacity can be determined both by calculation method and by testing piles by static load. However, the static load testing method according to conventional methodology has the following disadvantages:

- the inability to separately determine the frictional resistance along the lateral surface and resistance under the lower end of the pile;
- labor intensity and duration of testing due to need to withstand for a long time each stage of the load to stabilize the settlement.

With a view to eliminate these shortcomings, a new method for determining the load-bearing capacity of pile was developed in Laboratory of geomechanics of IPRIM RAS [7]. This method is based on the dynamometric method of testing samples to determine the long-term strength proposed by prof. S.S. Vyalov [8].

The essence of method proposed by S.S. Vyalov is that to a sample tested for uniaxial compression through a rigid dynamometer is applied an arbitrary initial voltage S_0 ; then its reduction in time (relaxation) and the time-related development of this process is recorded. From the obtained curves one can determine the form of the creep equation and values of relevant parameters. Taking the creep equation in the form:

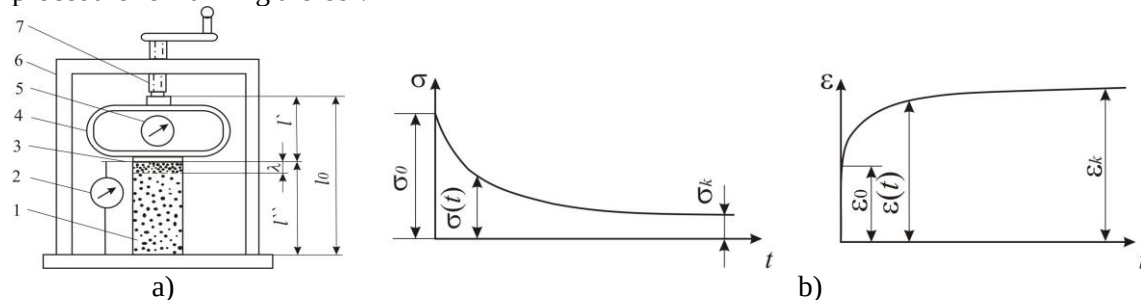
$$\varphi(\gamma) = \tau\psi(t) \quad (1),$$

and supposing $\varphi(\varepsilon) = A_0\varepsilon^m$, the creep function $\psi(t)$ as determined as

$$\psi(t) = A_0 \frac{[\varepsilon(t)]^m}{\sigma(t)} \quad (2),$$

where $\varepsilon(t)$ - is the sample deformation; $\sigma(t)$ - is the varying dynamometer voltage determined as per Fig 1 b).

If the initial voltage is set close to the conditionally instantaneous strength value, the final value of the stress as a result of relaxation will be close to the long-term strength limit, since the deformation stabilization can be regarded as achieving equilibrium between the acting external load and the internal forces of soil resistance. Below in Fig. 1 is shown the scheme of the dynamometer test and the procedure for running thereof.



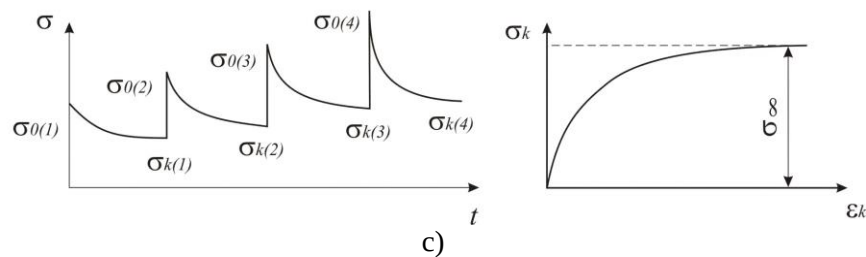


Figure 1. a) the diagram of dynamometer instrument: 1 - the sample, 2 - the displacement sensor, 3 - the die, 4 - rigid dynamometer, 5 - displacement sensor of the dynamometer, 6 - the frame, 7 - screw load device, b) the test results for the single loading, c) results with stepwise loading

The above procedure was used as a basis for new technique for determining the piles bearing capacity. In this case, instead of the specimen tested for uniaxial compression by vertical load in the creeping relaxation mode, the real pile was tested. It is important to note that using pile driving technology as per this technique, the actual bearing capacity of each pile without any additional costs can be determined, thus allowing to reduce the construction costs and increase the reliability of the pile foundation. However, this approach does not allow one to separately determine the bearing capacity of pile under the lower end and along the lateral surface (depending on the depth of immersion).

The essence of the new proposed method [7] is that the test pile is immersed by a static load at some depth; then the pressure in the jacks is no longer pumped up and the pile is tested in the creep-relaxation regime (CRR). In process thereof, when the pile creep deforms in the jack, a pressure drop occurs. The stabilized value of final pressure can be considered as the bearing capacity of a pile immersed in a given depth, since the external forces come into balance with the forces of pile resistance to indentation. Then a step-increasing pulling load is applied to the pile, where each step is tested in the creep-relaxation regime as well. The maximum value of the stabilized pulling out load can be considered as the sum of frictional forces along the lateral surface of the pile immersed to a given depth. The difference in the load of indentation and pulling out will be equal to the resistance of pile under its lower end. By immersing the pile at different depths and testing it at each point in the manner described above, it is possible to obtain a separate resistance along the lateral surface and below the lower end at different areas thereof along the depth. Figure 2 shows the diagram and test results of the method proposed.

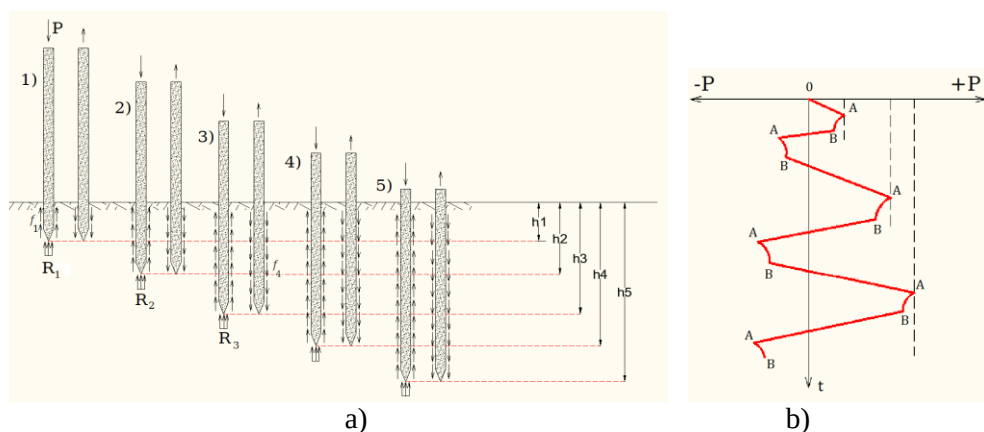


Figure 2. Testing of piles in the creep-relaxation regime according to the proposed method: a) test diagram; b) test results

For the experimental verification of the proposed technique in laboratory and field conditions, the series of comparative tests of piles in the creep-relaxation regime, in the dynamic load mode and in the static loading regime using the traditional methods have been carried out. To make laboratory tests more consistent with field conditions, a part of the experiments was carried out in a soil tray with vacuum pre-loading simulating the natural ground pressure [9]. For this purpose the soil in tray was isolated from the atmosphere by an airtight film, whereas air was pumped out from the soil pores with a vacuum pump. As a result, the compressive hydrostatic pressure acting on the soil skeleton was close to atmospheric pressure, which corresponded to a pile depth equal to about 6 meters. Figure 3 shows photographs of laboratory tests.

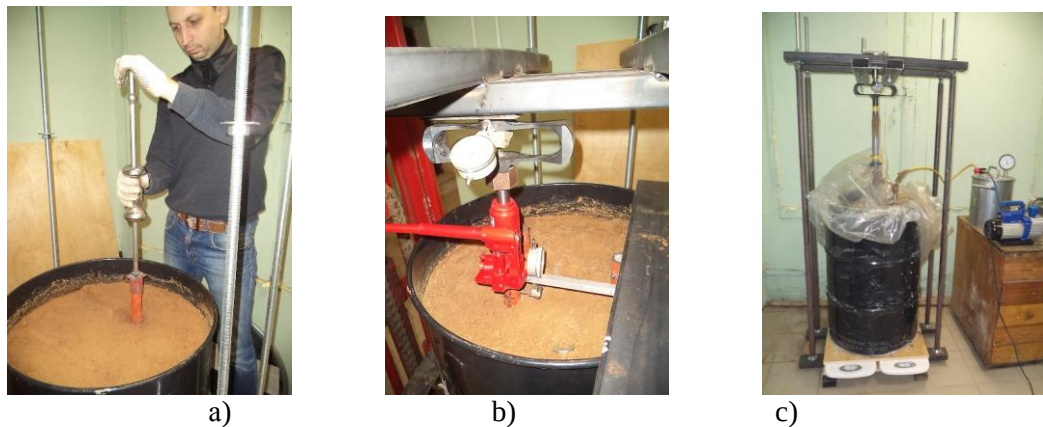


Figure 3. A series of laboratory comparative tests of models of piles by the various methods: a) tests of piles with dynamic loading; b) testing of piles with static load in the CRR mode; c) testing of piles in a soil tray with vacuum loading in the CRR mode

Figure 4 shows a diagram and photographs of field comparative tests during which one pile was tested in accordance with standard procedure by a static load, and the second one - in the creep-relaxation regime. In addition, during the tests the pressure values were determined; this pressure is transferred from the external load to foundation under the lower end of piles and under the foundation grillage bottom [10].

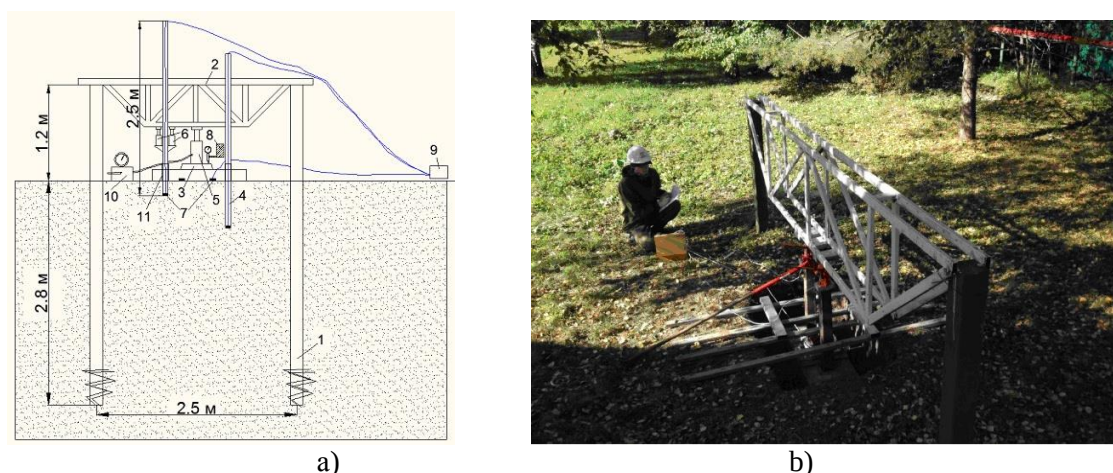


Figure 4. Field comparative tests: a) diagram of the field installation for testing piles: 1- screw anchor; 2- thrust truss; 3 - foundation frame; 4 - pile model; 5 - jack; 6 - jacks for pile installation; 7- measuring cells; 8- measuring frame with indicators for measuring the foundation frame settlement; 9 - tensor station; 10 - pumping station. b) photo of the field installation

The experiments were carried out on morainic loams forming the sides of the Uglich water reservoir [11]. The results of tests in the form of graphs of the dependence of precipitation on the load are shown in Figure 5.

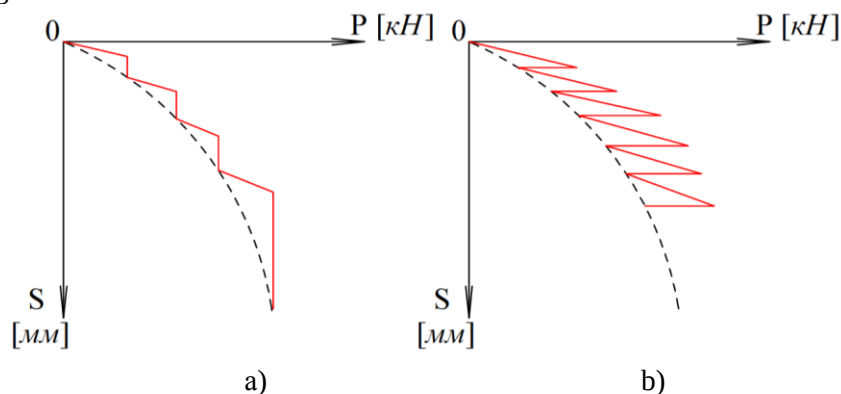


Figure 5. Result of field comparative tests: a) static load performed by standard method; b) made in CRR mode

In Russia about 63 % of the territory is in the permafrost grounds spreading zone. In connection with climate changes and permafrost degradation, the existing buildings built according to principle of permafrost conservation on piles frozen into the ground begin to experience the additional deformations due to decrease in bearing capacity of the piles.

Tests in the creep-relaxation loading mode can be effectively used to determine the bearing capacity of piles frozen in permafrost soils at the different negative temperatures during sole experiment. This procedure is similar to the procedure for determining the long-term cohesion of frozen soils at different temperatures [12]. The essence of the proposed technique is that the pile frozen into the soil is stepwise loaded with a static load, and each such stage is tested in the creep-relaxation regime. After determining the maximum stabilizing load on pile at a given negative temperature τ_3^0 , the temperature of the massif with the use of heating is changed by some amount up to value τ_2^0 ; so that the pile leaves the equilibrium state, the load relaxes, and its stabilizing value can be considered as bearing capacity of the pile under new value of negative temperature τ_2^0 . The test scheme and the results of the experiments are shown in Figure 6.

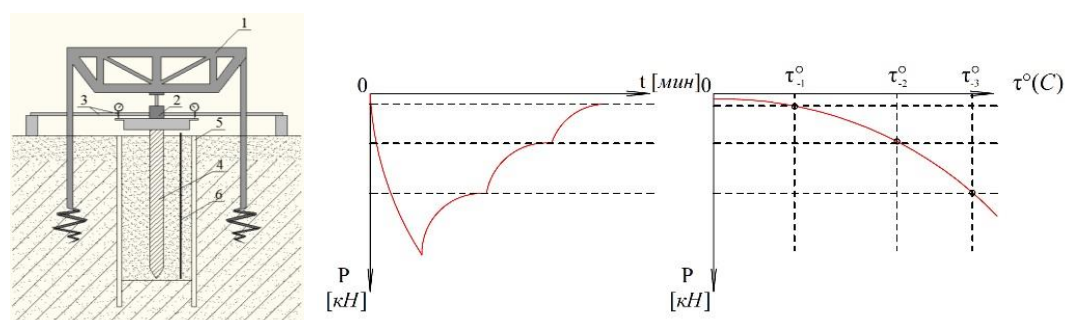


Figure 6. Tests at various negative temperatures: (a) test diagram: 1 - thrust truss with anchors; 2 - hydraulic cylinder; 3 - measuring system; 4 - pile frozen into the ground; 5 - heating device; 6 - temperature sensors; (b) graph of load dependency on time; (c) plot of the bearing capacity of piles for different negative temperatures

2. Conclusions

1. A new technique for separately determining the pile resistance under the lower end and along the lateral surface in the creep-relaxation regime at various depths in the course of one experiment has been developed and experimentally tested in field and in laboratory conditions.

2. Has been developed new technique for determining bearing capacity of piles in the creeprelaxation regime frozen in permafrost soils at different temperatures in the course of one experiment.

3. The developed methods allowed significantly reducing the time and cost of testing and increasing their accuracy. In the long run this leads to significant savings in construction costs and the increased reliability of the pile foundation in various engineering and geological conditions.

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